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Improving the accuracy of micro injection moulding process simulations

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Abstract

Process simulations in micro injection moulding aim at the optimization and support of the design of the mould, mould inserts, the plastic product, and the process. Nevertheless, dedicated software packages for micro injection moulding are not available. They are developed for macro plastic parts and are therefore limited in the capability of modelling the polymer flow in micro cavities. Hence, new strategies for comprehensive simulation models which provide more precise results open up new opportunities and will be discussed. Modelling and meshing recommendations are presented, leading to a multi-scale mesh of all relevant units of the injection moulding system. The implementation of boundary conditions, e.g. machine and venting, and results illustrating their importance on the simulation accuracy are presented.

1 Micro injection moulding simulations

Micro injection moulding (μ IM) is an efficient replication technology for the mass production of micro plastic parts. Consequently, simulations of the μ IM process become more and more interesting and relevant. They aim at reducing product time-to-market, optimizing resources by reducing re-engineering and development time, optimizing mould design and process settings before production. μ IM simulations still yield improper quantitative results due to the development of available simulation software for macroscopic plastic products. Relevant microscopic effects are not or only inadequately implemented and only qualitative predictions about the behaviour of polymer and process can be made for micro plastic parts. However, the numerical results can be significantly improved by implementing the whole injection moulding system, i.e. applying the correct strategies while building the complete part-tool-machine model.

2 Study case and validation experiments

The study case was a micro channel test structure with channels and walls of various widths and depths which represent different microfluidic structures in the sub-millimetre dimensional range (see Fig. 1, left). Experiments for comparison and simulation input were conducted on a small-sized injection moulding machine (Engel ES 80/25 HL-Victory, 18 mm screw diameter) using the acrylonitrile butadiene styrene (ABS) Novodur P2H-AT polymer grade. Melt and mould temperatures of the simulations were set to 220 °C and 80 °C, in accordance to mean values measured by the machine's temperature sensors (220.0 °C \pm 0.1 °C and 82.0 °C \pm 1.9 °C). The commercially available software Autodesk Simulation Moldflow Insight 2013® (ASMI) is used for the present work.

3 Simulation setup (modelling, meshing)

The feed system of micro plastic parts is usually of larger or at least similar volume than the actual part. Despite from the trend of reducing the size of the feed system, it still accounts for 40-90 % of the total injection volume. Hence, it has significant influence on the simulation results (e.g. filling time) and 3D modelling of part and feed system becomes necessary to obtain the required accuracy. To improve results in μ IM simulations, a comprehensive model including all elements involved in the process must be set up. Meshing an entire μ IM system including part, feed system, mould structures, and machine parts by a very fine mesh is barely feasible due to the generation of too many elements and unmanageable computation time. A multi-scale mesh combines therefore a fine mesh at micro features, curved surfaces, and short edges and a coarse mesh at feed system and less relevant areas as mould components (see Fig. 1, centre). The typical mesh size is in the range of few tens to hundreds micrometres for thin micro features and bulky part features, respectively, and up to few millimetres for less relevant areas (e.g. sprue). Furthermore, it is recommended to have at least 10 layers of solid elements through the thickness. Major influences such as the delay due to the actual machine acceleration and the

resulting actual polymer flow rate are not taken into account in default simulation setups. It is hence recommended to implement the actual speed profile of the injection moulding machine based on experimental data to reflect its characteristics as realistic and precisely as possible. Besides, it is advantageous with regards to the prediction of injection pressure to model nozzle and barrel with their actual geometry to grasp their influence on injection pressure and time.

The software enables to simulate the influence of venting on the filling of the examined part. Applied vacuum is assumed as default setting. If the mould contains venting structures, it makes sense to include the venting analysis with venting channels based on the real dimensions. Even if no dedicated venting structure exists in the mould, the air in the cavity escapes through the gap between the two closed halves of the mould. The flow resistance of the gap can have tremendous influence on the injection pressure, as the machine has to exceed the counter pressure built up by the compressed air.

4 Results

It can be observed in the simulation results that the machine geometry and the venting analysis both improve the results (see Fig. 1, right). The simulations clearly yield lower values for all three investigated measures. The part weight is most stable and already the default simulation setup reaches 96 % of the actual value. The implementation of the machine geometry improves the injection pressure and the injection time by 22 % and 15 %, respectively. Although no venting structures are existent in the mould, implementing a venting analysis was found to be necessary, as full venting (i.e. vacuum) cannot be assumed. Depending on the height of the venting channel used for modelling the parting gap of the mould, the venting analysis is capable of improving the output again by up to 30 % and 9 % for injection pressure and time respectively.

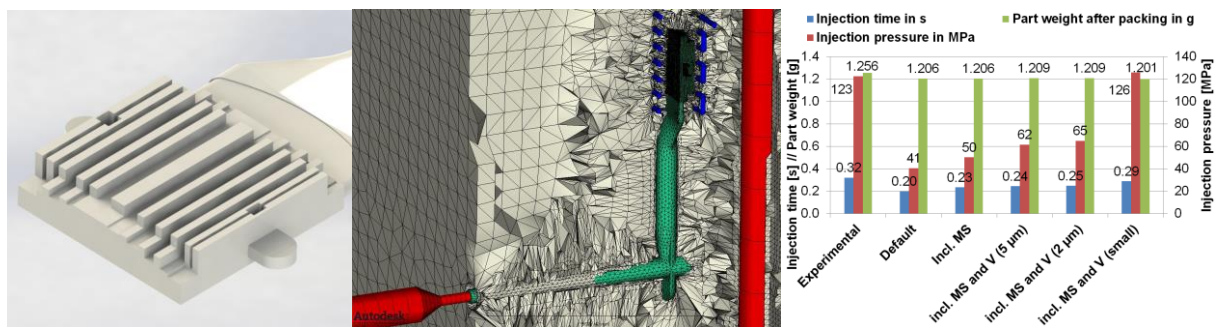


Figure 1: *left*: CAD model of moulded plastic part with indicated gate; *centre*: comprehensive simulation model including part, feed system, mould, machine geometry; *right*: process parameters (injection time, injection pressure, part weight) for different simulation settings (MS = machine structure, V = venting).

5 Conclusion

The modelling and meshing of all relevant units (part, mould, machine) of the injection moulding process was implemented based on the ability to create a multi-scale mesh with a mesh size in the millimetre range down to micrometre range. Scope and method of implementation of the simulation model can have large impact on the simulation results. By incorporation of the actual process boundary conditions, machine geometry, and machine behaviour, the results can be improved significantly. It was shown that the implementation of venting simulations is necessary due to the assumptions in the software and that it improves the simulations output. The presented new simulation model and software functionalities are also accompanied by new questions, e.g. about the necessity of modelling moulds by CAD files or the adequateness of simpler representations. New parameters have arisen and their influence on the simulation needs to be addressed in the future, e.g. mould material, size of venting channels and the gap between two mould plates without actual venting structures.

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